Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

NOTES ON AN ANT.

BY ADELE M. FIELDE.

There is no regeneration of the antennæ.—A queen of *Stenamma fulvum piceum*[1] deprived of her antennæ in July, 1901, lived in one of my artificial nests with workers and other queens until January 5, 1902, and gave no indication of regenerating the lost organs. Of the many ants whose antennæ were wholly or partially excised by me in 1901, in the experiments made upon the ants' sense of smell,[2] some lived several months, but none ever showed sign of regenerating any excised part.

Ability to live in isolation.—On the 27th of August, 1900, I took three workers from an apple-core lying by the roadside and segregated them in a Petri cell, from which they were never removed. One died February 23, 1902; one died March 1, 1902, and one is still living, September, 1902, the survivor having lived alone more than six months. She busies herself with the inert young that I lend to her and reclaim before they hatch, and she appears to be healthy and happy. She is wholly tame, and evinces no desire to leave her cell when I take off its cover; but she seems to enjoy disporting herself upon my hand, or upon the hand of another person, where she will voluntarily stay for long periods. She appears to have, concerning human hands, unexplained preferences which do not depend on acquaintance, temperature or race.

Familiarity with the nest-aura does not reconcile aliens.—Two of my small nests,[3] one containing ants of the C colony, the other containing ants of the G colony, have stood in juxtaposition one year, and have been cleaned weekly with the same appliances, but the inmates of the two nests continue to fight each other on meeting, as they did when first taken from their natural nests.

---

[1] The writer is in her third year of study of this ant. It is the species under consideration in this paper in every case, unless another species is named.

[2] "Further Study of an Ant," *Proceedings of the Academy of Sciences of Philadelphia,* October, 1901.

[3] "Portable Ant Nests," *Biological Bulletin,* Vol. 2, No. 2, 1900.

Kings.—The kings have the distinctive odor of their blood relations.—July, 1902, I isolated, each in a Petri cell, eight deälated queens, more than one year old, and representing two communities. Into each of the cells I introduced, one at a time, several kings, but a few days or few weeks old, and with no previous association with any of these queens. In every case the queen was at once friendly, and continued for many days to be friendly, with all kings of her own colony, but was so hostile to kings of any alien colony that she avoided or killed every alien king introduced. She must have recognized colony odor in these kings. The kings appear to be deficient in the sense of smell. They at times, especially in the light, and on warm days, become wildly amorous upon contact of the head with a queen, a worker or another king, regardless of the lineage of either. The kings are not clever, never follow a trail, never take part in the care of the young, and are at all times dependent. They can lap food for themselves; but I have seen so many as three kings feeding at the same time from the mouth of one worker, while other kings stood around as if waiting their turn to be fed.

Queens.—It may be said of the queens that while virgin they manifest marked preference or dislike toward certain kings. Having once mated they afterward permit no close approach of an alien king. They condone the stupidity of kings of their own lineage, and tolerate from them attentions to which no response is conceded.

It has been affirmed that workers remove the wings from fertilized queens. That a queen may drop her wings without assistance was shown by two living in my nests. Both were hatched on August 5, 1902, from pupæ taken by me from the natural nest on August 3, and they both mated in captivity on August 22, when seventeen days old, with kings a few days old, and of their own colony. As soon as they had mated I again isolated each, and each dropped her wings within a few days upon the floor of her solitary cell.

A queen may defer mating for a year at least, and then mate with a king a year younger than herself, and may, later on, begin the laying of eggs. Light and warmth appear to be required for stimulation of the king and queen to mating, and it may be that queens hatched late in summer do not mate until the next succeeding summer. A winged queen taken by me from the natural nest of the C colony, August 22, 1901, had no opportunity to mate until September 24, when I put into the artificial nest where she lived several kings of the H colony, just taken from the ground. These kings all died within a few days, and the queen probably did not mate during 1901, as she retained her wings and laid no eggs throughout the winter of 1901–1902. She had no association with any king between September, 1901, and July 6, 1902, when I put into the Petri cell where she was then isolated a king of her own colony, five days old. She at once seized him gently by a wing, and presently licked him from end to end. She could not have mated earlier than July 6, and may not have mated until August, when I put other kings and also workers, all of her own colony, into her cell. On August 20, 1902, she lost her wings, having worn them a year or more. She laid her first egg on August 24, four days after losing her wings.

Another winged queen, also taken from the natural nest of the C colony on August 22, 1901, had no opportunity to mate until September 21, when I put into her habitation two kings of her own colony. She probably did not mate with either of them, for she retained her wings and laid no eggs throughout the winter of 1901–1902. There were no males in the nest where she lived from September, 1901, to July 13, 1902. On the latter date, after she had been isolated one month, I put into the Petri cell where she then lived a king of her own colony, and several workers. The king was but four days old, but may have mated immediately with the still winged queen. She lost her wings on the 10th of August, having worn them nearly a year since her capture. On the 14th of August she laid her first egg, and on the 20th she had eight eggs.

Memory.—Have the ants an intellectual memory ?

Experiment a.—In one of my artificial nests were four deälated queens of the C colony, taken by me from their natural nest near Wood's Hole, Mass., September 7, 1900, with workers. On the 23d of September, 1901, I put into this nest some pupæ of *Formica fusca subsericea,* and five days later one of these pupæ hatched, and was permitted to live with the resident Stenammas. The

Formica was somewhat larger than either of the Stenamma queens, and was very active. She remained in association, at times, with these queens until November 28, a period of two months, and was then finally removed from their nest. Five and a half months later, May 11, 1902, I put the four queens into a clean Petri cell, and introduced to their cell a *Formica fusca subsericea* from Central Park, New York City. The introduced Formica exhibited great fear in the presence of the Stenamma queens, and made energetic efforts to escape from the cell; but the queens showed neither fear nor dislike of the Formica, and never opened their mandibles when I forced the Formica to touch them. The fears of the Formica gradually subsided, and after two weeks' residence she would touch antennæ with the queens in most friendly fashion. The Formica was thereafter often huddled with the queens, and she lived with them until May 31, 1902, when the four queens were killed by an accident. The Formica survived and I put her into a similar cell with C colony queens that had never fostered a Formica. These queens separately and together attacked the Formica and killed her after two days' persecution. It is possible that the odor of the Formica remained in the nest inhabited by the four Stenamma queens, and that they had not to exercise memory in the case. But the odor of the Wood's Hole Formica and that of the Central Park Formica was not identical, for I put *Formica fusca subsericea* of these two places together and found that they fought each other to the death.

Experiment b.—On the 22d of August, 1901, I sequestered pupæ and larvæ from the natural nest of the C colony, and then segregated ants hatched therefrom between September 4 and September 10. These segregated ants had no association with any other ant. On the 26th of September a large *Formica fusca subsericea* hatched out from a pupa that I had put into their cell three days earlier, and it was kindly cared for by the little Stenammas, although it was four or five times their size. On the 6th of October, the Stenammas being about one month old and the Formica ten days old, I separated them, putting the Stenammas into one clean Petri cell and the Formica into another. The inhabited cells were respectively cleaned once a week,[4] and were cleaned seven times. On the 24th of November, after fifty days of separation, I put the Stenammas, now only two in number, into a clean cell, and introduced the Formica. The Formica was in as complete a panic as could have been one of its kind that had never seen a Stenamma. She ran from the Stenammas, snapped at them when forced into proximity, and gave starts of terror when coming inadvertently into touch with them. The Stenammas, on the contrary, showed neither fear nor dislike of the big foster-child that had been returned to them. The fear manifested by the Formica gradually diminished, and after about two weeks together the Formica would voluntarily approach and touch antennæ with the Stenammas.

---

[4] The cells were cleaned, after temporarily removing the ants to another clean cell, by washing the cell and its enclosed sponge with

I then took two Stenammas of the same size and lineage as these fostering ants, placed them in conditions in all respects similar, and introduced this same Formica to their cell. The Stenammas at once attacked the Formica, and would have slain her had I not intervened. I then returned her to the fostering ants, and left her with them one week longer.

I then repeated the separation of the two Stenammas and the Formica, again keeping them apart fifty days, and likewise cleaning the two cells once a week. On February 5, 1902, I again reunited the three ants, and this time found that the memory of each species for the other appeared to be perfect. There was no manifestation of fear nor repulsion on either side. Perhaps the increased age of the Formica, or her longer residence with the Stenammas previous to the second test enabled her to better remember them. She died a natural death the 10th of February.

In order to ascertain the existence of fighting qualities in these two Stenammas, I put into their cell aliens of their own species and found that they retained the habitual aversion of their kind toward strangers.

On the 11th of June, 1902, the same two Stenammas, then much engrossed in the care of pupæ, fiercely attacked Wood's Hole *Formica fusca subsericea* that I introduced into their cell. This Formica was not of the same colony as the one that they had fostered.

These two Stenammas seem to have remembered for fifty days

---

soap in hot water, soaking in boiling water, and rinsing in running water. A full description of the cells used in these experiments may be found in "A Study of an Ant," *Proceedings of the Academy of Natural Sciences of Philadelphia,* July, 1901.

an ant of a different subfamily from themselves. They had never met any other ant of that subfamily.

Experiment c.—On the 23d of September, 1901, I put into an artificial nest containing queens and workers of the C colony some pupæ of *Formica fusca subsericea,* and on the 29th of September one of these pupæ hatched, and continued to reside with the Stenammas. On the 20th of October I removed the Formica to a Petri cell, which was cleaned weekly, and I kept her there until November 24, thirty-five days, when I introduced to her cell two queens and four major workers from the nest in which she had been hatched. The Formica exhibited great fear, as these ants usually do when brought into the presence of Stenammas; but the Stenammas appeared to be wholly friendly to the Formica. It is possible that the Stenammas have a better memory than have the Formicas, or it may be that her odor had continued to be manifest in the nest of the Stenammas, modifying their action in regard to their former associate.

These Stenammas are very discriminating concerning the odor of all ants introduced into their habitation, whether it be of their own or other maternal lineage.—An example of the persistent aversion of these ants toward the odor of an alien community was given by the residents in two of my artificial nests. In nest M, ants of the C colony, captured September 7, 1900, had reared during the summer of 1901 pupæ introduced from the E colony, and had also reared from the pupa-stage two *Formica fusca subsericea.* The fostered workers of the E colony remained in the nest; the two Formicas were removed December 1, 1901. On the 6th of June, 1902, I took all the ants, including queens and workers, in this nest and put them into a similar artificial nest inhabited by queens and workers of the C colony that had had no association with other ants since their capture from the natural nest, August 22, 1901. There was instant battle between the residents and the introduced ants, and the fighting continued during the three following weeks, until all the ants reared from the E colony pupæ had been exterminated.

In other nests, where no ants of alien lineage had been reared, ants of the C colony immediately affilated after two years of separation. That the colony odor and not personal acquaintance determines this affiliation may be illustrated by a single example.

On August 14, 1902, I had an artificial nest where were many queens and workers with inert young, all taken from the natural nest of the C colony, and established in my nest on the 7th of the preceding June. Into this nest I then introduced a young worker, the offspring of a C colony queen and an E colony king, whose whole existence had been passed in an artificial nest that had been established by me August 22, 1901. The inmates of this nest had never since its establishment associated with outside ants, nor entertained alien offspring. The young ant was amicably received in the nest into which she was introduced, and was not once nabbed during the succeeding half-hour, while she moved about fearlessly among the hundreds of residents. Her having had an alien father did not make her less acceptable to her mother's blood-relations.

The male parent does not influence the odor of the progeny.—Ants reared from pupæ segregated before hatching, never having associated in any wise with other ants, and having their own odor as their sole criterion, manifestly find that criterion duplicated in the odor of ants of about their own age, when these ants are of the same lineage as themselves on the maternal side, regardless of their paternity. The hereditary odor descends through the mother, and is unaffected by the father, whether he be of the same lineage as the mother or of an alien colony. The mother alone determines the intrinsic odor of her progeny.

In August, 1901, I arranged eight new artificial nests, for the rearing of ants having a recorded parentage. Into four of these nests I put virgin queens of the C colony with kings of the C colony; and into four of the nests I put virgin queens of the C colony and kings of either the E or the H colony. About fifty workers of the C colony were put into each nest to act as nurses to the expected young. During the ensuing year young was produced in all of these nests, and with these young ants I made experiments, as recorded below, during the year 1902. The ants used in the experiments were, unless otherwise indicated, hatched from pupæ that had been removed from the nest several days before hatching, isolated or segregated in a clean Petri cell, and never brought into association with any other ant previous to the time of use in the experiment. Such ants had, then, no criterion of correct odor, other than that of their own bodies.

Experiment a.—May 5. Into a clean Petri cell I put a worker twenty-five days old, the offspring of a C colony queen and an E colony king. With this worker I put another, fifteen days old, whose parents were both of the C colony. The two affiliated at once.

Experiment b.—May 10. Into a Petri cell occupied by three workers, from seven to twelve days old, the progeny of a C colony queen and an H colony king, I introduced one by one three workers, from two to twelve days old, the progeny of a C colony queen and a C colony king. The affiliation was in each case immediate. They behaved toward each other as if they had always been associated. I then put the six young ants into an artificial nest inhabited by queens and workers of the C colony, and they were adopted without examination.

Experiment d.—June 11. Into a Petri cell occupied by five workers, from two to five weeks old, the progeny of a C colony queen and a C colony king, and engaged in the care of introduced larvæ, I put a worker a few days old, the offspring of a C colony queen and an E colony king. The callow was adopted into the group without objection of any sort.

Experiment e.—June 11. Into a Petri cell occupied by six workers, between one and three months old, the progeny of a C colony queen and a C colony king, and engrossed in the care of introduced larvæ, I put a callow a few days old, the offspring of a C colony queen and an H colony king. The callow was immediately accepted by the residents.

Experiment f.—August 5. Into a Petri cell I put a callow two days old, the offspring of C colony parents, and hatched in one of my artificial nests that had been established just one year. With this callow I put one of about the same age hatched in the ancestral wild nest of the same colony. The two callows instantly affiliated, though they must have had different fathers.

The following experiments show not only that the mother alone determines the intrinsic odor of her offspring, but that the hereditary odor is modified by the age of the ant. As in the foregoing experiments, the workers first placed in the Petri cells are those sequestered while in the pupa stage, having no acquaintance with any ant other than those of their own segregated group of workers.

Experiment g.—February 23. Into a Petri cell occupied by two workers about one month old, the progeny of a C colony queen and a C colony king, I put two large and dark-colored workers taken from the ancestral nest in the preceding August. Each of the two residents instantly attacked an introduced adult, and used their stings with such violence that I removed the adults through fear of endangering the lives of the junior ants. I then introduced two other workers, also of the C colony, but less deeply colored than those I had removed. The two parties avoided each other, always associating by twos during several hours; but within a day they were huddled in one group. Three days later I put the four into a C colony nest, and they were all amicably received there. There was difference of odor, perceived at the first meeting, although all the ants were of the same colony.

Experiment h.—May 9. Into a clean Petri cell I put five workers, from twelve to fourteen days old, the progeny of a C colony queen and an E colony king. With them I put five workers, four of them from twelve to twenty-five days old, one of them sixty-five days old, the progeny of a C colony queen and a C colony king. The two groups had each been segregated from the pupa stage of existence. All the nine ants that were less than twenty-six days old affiliated quickly. The oldest ant was repeatedly attacked by the ants that had not previously been associated with her, and was dragged unresisting from the group and cast down on the opposite side of the cell. After being thus ostracized for about three days she was received into full fellowship. As this ant had the same parentage and had spent all her life in segregation with the four younger ants that were at once accepted into full fellowship, her age appears to be the sole cause of her having been differently treated, and indicates a different odor due solely thereto.

Experiment i.—June 14. Into a Petri cell occupied by three workers, ten days old, the progeny of a C colony queen and an E colony king, and engaged in the care of introduced larvæ, I put a worker, also ten days old, the offspring of a C colony queen and a C colony king. There was instant affiliation. I then introduced one by one ants of about the same age, but of diverse paternity, the mothers all being of the C colony, and all were amicably received, and were permitted to at once join in the care of the larvæ. When the group numbered ten, I added from a nest of the C colony a queen and an adult worker. Both were at once attacked and dragged away to the side of the cell opposite the larvæ. The queen was soonest tolerated, and within a day or two was permitted to join the group; but the adult worker was ostracized for eight or nine days.

Experiment j.—June 16. Into a Petri cell occupied by two minims ten days old, the progeny of a C colony queen and a C colony king, and engaged in the care of inert young, I put two major workers from an artificial nest of the C colony. The majors were much older and stronger than the two resident ants, but they submitted to being repeatedly dragged by the minims away from the nursery, and they were not allowed to join in the care of the young until after many days, one being ostracized until June 30, the other until July 4.

Experiment k.— July 27. Into a Petri cell containing four workers, each twenty-three days old, the progeny of a C colony queen and a C colony king, and engaged in the care of introduced pupæ, I put, one by one, five young ants, just taken from the natural nest of the C colony. Every one of these introduced ants was dragged to the side of the cell opposite the nursery, and were there cast down. If I lifted the cover of the cell they were dragged outside it.

I then chose callows from the natural nest, and likewise introduced them one by one into this cell. All were received without sign of dislike. In a few hours or days all the ants were grouped together about the pupæ.

Experiment l.—On the 22d of August, 1901, I segregated pupæ that hatched between August 27 and September 1, and I segregated the callows as soon as hatched, so that they never associated with other ants. On the 25th of the following December, the ants being then four months old and fully colored, I put into their Petri cell a queen of their colony taken while still winged, and at the time when these ants were taken as pupæ from the ancestral nest. This queen had since been kept in an artificial nest, with no other inmates than queens and workers of her own colony. The sequestered ants at once attacked and dragged the queen, but did not maim nor kill her. They continued to drag her away from the inert young and to ostracize her for about ten days, and then they gradually accepted her company. This indicates that no vast amount of time, perhaps not more than some forty or fifty days, are required for modification of the odor of the individual ant.

Other experiments invariably brought similar result. Whenever ants are hatched from sequestered pupæ, and reared without association with older ants, they always drag old ants of their own lineage away from the inert young, and sometimes refuse for many days to tolerate them near the nursery. The workers, on the other hand, never drag younger ants of their own maternal lineage away from the nursery, nor do they retaliate when the callows attack them. I have seen a very small pale callow tyrannize over a large deeply-colored adult for consecutive weeks.

A cause for the hostility of one colony to another of the same species and variety is a difference of odor, coincident with difference of age in the individuals composing the colony.

A queen, after mating, may settle in new ground, deposit her eggs, rear from them her progeny, and herself determine the inherent hereditary odor of the colony, which will be the same for all ants of that queen's lineage hatched at about the same time. Such progeny may be separated and kept segregated in sections for long periods, and the individuals of any section will at once affiliate with those of any other section on reunion. The pupæ may be segregated, and the subsequent affiliation of the ants produced therefrom will be equally complete, whether a queen be included in each division or not. The progeny of sister queens of the same age will instantly affiliate with each other or with the aunt-queen, provided that the segregation of each division has been perfectly maintained, and that there is little difference in the age of the ants.

Attacks made upon ants of the same lineage, when such are introduced into a segregated group, are more or less violent in proportion to difference of age between the residents and the introduced members.

A group may rear successive broods, in successive seasons, from the eggs of the same queen, and these broods will from their earliest days to their latest recognize the odor of all the kindred with which they were associated during the first few days of active existence. Their standard of compatibility is then formed, and they will defend nest and young against the approach of all ants whose odor disagrees with that standard. It follows that ants in a nest containing queens and workers many years old would have a different standard from that of any more lately established nest, even though all were of the same lineage. This explains the fact that colonies apparently alike, and with nest-exits but a few feet apart, sometimes show bitterest hostility to one another. It also explains the fact that ants taken from the extremes of an ant-domain fifty yards in diameter, and kept apart for two years, amicably reunite, provided that no young has hatched in either segregated group. It furnishes also explanation of the highly variable behavior of the ants of the same lineage toward one another when brought together after segregation; and it enables one knowing the exact conditions to accurately prophesy what a given ant will do on meeting another given ant of her own lineage.

In the following experiments, which are but a few examples from among many made by me in the summer of 1902 for the purpose of ascertaining the cause of hostility between colonies of the same species, all the ants were of the C colony, much used by me because of easy access to its populous natural nest.

For the ants a year or more old, I used queens and workers of this colony that were captured by me on August 22, 1901, and that have since been kept by me in small artificial nests, where no pupa has been allowed to hatch, and to which no ant has ever been introduced from outside.

When the ants did not differ in size or color sufficiently for me to thereby distinguish them, I marked those that I desired to observe.[5]

The ants depended upon to show the feeling of their kind toward such as were introduced, were all engaged in the care of inert young in Petri cells, where they had been for some days or weeks established as a family group. When I was about to use any such cell in experiment, I sometimes introduced an ant of an alien colony in order to ascertain the presence of fighters among the residents of the cell. Such aliens were always removed before the experiment.

The ants could not carry intruders outside the cell, unless I lifted its cover. I therefore considered, in these experiments, the seizing and dragging of any ant away from the larvæ pile and across the cell as equivalent to the casting out of that ant from the nest. I sometimes lifted the cover and allowed the resident ant to carry an intruder outside it. The Petri cells permitted more close and constant observation of the ants concerned than would have been possible in any other residence.

---

[5] I mark the ants upon the top of the abdomen using dried varnish, into which water-color paint has been rubbed before drying. The varnish is softened for immediate use by a drop of chloroform. The ant is gently held by the head until the chloroform has evaporated from the dab upon her abdomen. This mark often remains upon an ant several weeks, and does not appear to influence her action nor that of her associates in the experiment.

Experiment m.—On August 25, into a cell containing forty workers, hatched between July 4 and July 16 from pupæ previously segregated, I put one by one three workers, each twenty days old, also hatched from sequestered pupæ, and also segregated to the time of the experiment. The introduced ants were all accepted without examination or attention.

I then put in a queen, captured June 7, and since deälated. She undertook at once to sort the resident workers, and to carry some of them out of the cell. She was attacked by a resident and I removed her.

I then put in an ant over one year old. She was seized and dragged across the cell, and this was repeated three times on her approach to the young, after which I removed her.

I then put in another ant over a year old. Five residents attacked her at once and so violently that I rescued and removed her.

I then put in a queen one year old. She was seized and dragged across the cell and I removed her.

I then put in another queen of the same age and she was treated likewise.

Experiment n.—On August 25, into a cell containing fourteen workers, all hatched on August 5 from segregated pupæ, I put a marked ant less than thirty days older than the residents. She was accepted without examination. I then put in a queen hatched on the same day as were these residents, and since mated and deälated. She was instantly accepted into the ant-group.

I removed her, and put in a queen one year old. She was three times dragged by two residents away from the young and across the cell, and I took her out. This queen had mated with a king of an alien colony, and had since reared progeny.

I then put in another queen, a year old, who had mated with a king of her own colony, and had since reared progeny. She was likewise attacked and dragged.

I put in adults of various ages, all more than a month older than these ants, and all were attacked. In these attacks on older outsiders the marked ant was active. She had never before met old ants.

Experiment o.—On August 25, into a cell where there was a queen who was hatched on August 5 among segregated pupæ, and who was isolated soon after hatching, I put seven workers all under three days old. The eight ants at once snuggled together.

Experiment p.—On August 26, into a cell containing fifteen workers, all hatched from segregated pupæ on August 5, I put a deälated queen, also hatched on August 5. The workers at once accepted the queen. As these ants had never before seen a queen, they must have been guided in their acceptance of her by smell rather than by feeling. Feeling would have surely revealed a difference between the conformation of the newcomer and that of their habitual associates.

After half an hour I removed this young queen, and put in a queen one year old. She was instantly seized and dragged across the cell.

I took her out and put in a worker more than one year old. She was violently attacked and I removed her.

I then put in an ant only a few days older than the residents. She was at once allowed to join in the care of the larvæ.

I then put in another deälated queen, also hatched on August 5, but since associated with older ants. She was nabbed and pulled, but was afterward licked, and in fifteen minutes was snuggled.

I took her out and put in another queen one year old. She was attacked and dragged across the cell three times before I took her out.

I then put in a worker about forty days older than the residents, but who had always been segregated with ants of her own age. She was attacked and dragged.

Experiment q.—On August 26, into cell A, containing many workers that had hatched August 7 from pupæ segregated August 3, and that had never since August 3 been protected from daylight, I put several workers that were also hatched on August 7 from pupæ segregated August 3 in cell B, and that had always been kept in darkness. They affiliated instantly, and without mutual attention. I likewise put into cell B several workers from cell A, with the same result.

At a later date, ants that had passed their whole pupa-stage in the light affiliated with those of the same age that had passed their whole pupa-stage in darkness, and *vice versa.*

Experiment r.—On August 27 I put into a clean cell three queens, one captured, deälated, September 7, 1900; one captured winged, August 22, 1901, and one captured, winged, June 7, 1902. All were deälated at date. These queens had all at some time associated with queens older and younger than themselves, and they at once associated amicably with each other.

I then removed from the cell the youngest of the three queens, and introduced one of exactly the same age as was she, but who had, during her twenty-two days of life, had no association with any ant older than herself. This young deälated queen constantly fled from the two older queens, and refused during two days to be driven or cajoled into touch with them. Meantime they snuggled each other voluntarily, though they had never before met.

Experiment s.—On August 28, into a cell containing a score of workers, hatched August 5 from pupæ sequestered August 3, I put, one by one, three workers of the same size and color as these resident ants, but twenty one months older, having been hatched between the 13th and the 21st of November, 1900. Each of the visitors was seized and dragged.

I took them out, and put into the cell, one by one, three workers, thirty-seven days old, and of the same size and color as the resident ants. Each of these visitors was received without seizure or nabbing.

I then took them out and put in a queen hatched August 5. She was at once accepted. I removed her and put in a deälated queen hatched in June. This queen was nabbed, but she immediately set herself to the regulation of her new family, and she successively picked up and carried across the cell seven young ants. As fast as she brought the ants from the ant-group at the larvæ-pile I removed them from the cell, and in half an hour she had settled in the midst of a serene family, where she appeared to be wholly acceptable.

I then took her out, and without returning the rejected workers, I put in a queen a year old. This queen was attacked with great violence by several residents together, and I removed her from the cell.

I then put in a queen that had lived in one of my artificial nests since September 7, 1900. She was likewise violently attacked, and I removed her.

Large and small workers, a year or more old, also met with hostile treatment.

The results from these and all other experiments recently made by me coincide with my observations during three years' study of this species, and confirm my view that the cause of that diversity of odor which characterizes diverse communities lies in the difference in the relative ages of the communities. The queen transmits her individual odor to her progeny, and it is probable, though not proven, that in successive seasons the odor of the progeny varies with the age of the producing queen, the odor being a product of metabolism.

Effects of light and color upon the ant.—The haste with which the wild ants catch up their inert young and scurry into darkness whenever their nests are uncovered indicates great sensitivity to light. In the summers of 1901 and 1902 I reared ants from the larvæ, letting them pass the whole pupa-stage in full daylight, both with and without ant-nurses, and I found that the ants thus reared had the same color and the same activities as had their congeners simultaneously reared in darkness.

Sir John Lubbock[6] has shown that the rays from which his ants withdrew were the ultra-violet, and Forel[7] has proven that his ants perceived these rays through the eyes. Accepting the results attained by these eminent myrmecologists, I undertook to give my ants opportunity for healthful living and for their ordinary domestic occupations in my glass nests, and at the same time to impel them to deliberate choice among the seven primary colors or some combination of these colors. I therefore established newly captured queens, workers and inert young in three sorts of dwellings, where my earlier experiments had shown that they could live comfortably for long periods. I used the maze which is minutely described in my paper, "Further Study of an Ant," and which is here represented in the drawing marked M; a portable four-roomed nest, made for these experiments, and represented in the drawing marked N, and a score or two of Petri cells about ten centimeters broad and one centimeter deep. All these habitations contained flakes of sponge saturated with clean water, and were suitably supplied with morsels of food for the ants. In none of their residences did I ever disturb the ants oftener than twice in a single day by any alteration of their environment.

---

[6] *Ants, Bees and Wasps*, pp. 211 to 217, Appleton & Co., New York, 1902.

[7] *Experiences et remarques critiques sur les sensations des Insectes.* Deuxieme partie, pp. 10–24. Como, 1900.

I put papers of vivid colors under the transparent glass floors of these habitations, offering always a choice between colors. In the maze four colors were presented; in the nest, three; in the Petri cells, two. During two months of experimentation in this line the ants never moved their young, nor themselves congregated upon one color in preference to another, nor did they in consequence of a change in the color of their floor, or of an interchange between black and white, ever remove from any spot upon which they had congregated. They gave no sign of regarding any quality in their floor other than its opacity, and the most vivid reds, greens and blues displayed there in full daylight failed either to entice or to agitate them.

Their behavior was very different when colored glass was used for transmitting the light that entered their abodes. In all cases diffused, not direct, sunlight was used in these experiments. The walls as well as the roof of the dwelling were transparent, and the superimposed colored panes extended two inches beyond the walls, so that the chosen light entered from every quarter except through the floor, which was always opaque white. This made the conditions nearly equal throughout the abode. The dwellings were placed upon a large table where the summer temperature was the same on all sides, and the diffused light from a large north window gave fairly equal illumination over the whole.[8]

The ants were not affected by the intensity of the illumination from rays of longer wave-length than violet.—I repeatedly interchanged the panes over a Petri cell, one-half of which was covered by a pane that shut out all rays except a few red ones, and the other half by a pane transmitting much red light. During a residence of several weeks in this cell the ants showed no preference for the less intense light.

I also covered one-half of a cell with a colorless pane, and the other half of the cell with a dark-violet pane transmitting, as shown by the spectroscope, all the colors of the spectrum. I could scarcely discern the ants through the violet pane. But during a residence of several weeks in this cell the ants, after two removals from the colorless to the violet side, remained for many consecutive days under the transparent glass, and I repeatedly interchanged the two panes without causing the ants to remove from under the one or the other.

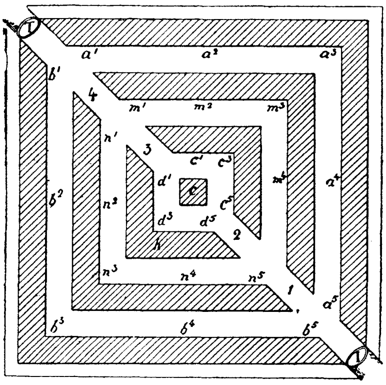
---

[8] These experiments were made at the Marine Biological Laboratory at Wood's Hole, Mass., in June, July, August and September, 1902.

The same indifference to the intensity of illumination was shown by ants placed in cells covered one-half with a double layer, the other half with a single layer of green glass; one-half with a double layer, the other half with a single layer of yellow glass; or one-half with a double layer, the other half with a single layer of blue glass. The relative proportions of the primary colors, from red to indigo, transmitted by the various colored panes varied greatly, as the spectroscope showed. But the ants apparently disregarded these proportions, and were hasty or deliberate in their action in direct ratio to the number of rays from the violet end of the spectrum.

It is probable that ultra-violet rays were transmitted with the violet ones in all of my experiments.

It must be constantly borne in mind that the ants are instinctively photophob. They always take shelter under an opaque covering when a choice is offered between darkness and any rays of light, even pure red.



M.

Experiment 1.—June 8. I put into the maze four queens, fifty adult workers and a half-teaspoonful of larvæ, and covered the maze with colored panes, each covering one-quarter of the maze, from side to centre. Under the spectroscope the panes showed the light transmitted to be as follows:

The red pane transmitted only red rays.

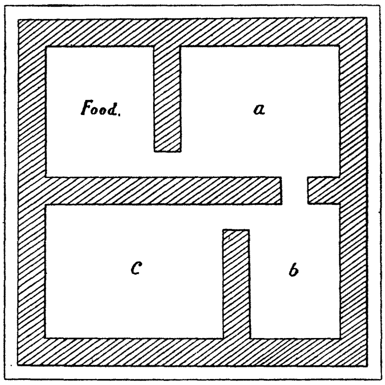
The orange pane transmitted red, orange, yellow, green, blue.

The green pane transmitted orange, yellow, green, blue, indigo.

The indigo pane transmitted yellow, green, blue, indigo, violet.

The ants spent thirty-eight days in the maze, and during that time made fifty settlements therein. Their first settlement, made by gathering the scattered larvæ and forming a single group including all the queens and workers, was under the red pane. I then placed the indigo pane over the group, interchanging it with the red, and the ants at once removed from under the indigo pane, and again grouped themselves under the red. Whenever I put the indigo pane over them they sooner or later removed from its light and settled under another pane, the total result being that they settled twenty-nine times under the red pane, ten times under the orange pane and eleven times under the green pane. Not once did they move from under the red, orange or green pane to the indigo. In removing, they as often settled on the side opposite as upon a side adjoining their last place of sojourn. All other conditions remained unchanged, making it certain that their removal was due solely to the interchange of the panes.

Their earliest removals from under the indigo pane were made in manifest haste, and were all made within a few minutes after I had interchanged the panes. But their haste gradually diminished, and on July 2, after the thirty-sixth removal, they remained several hours under the indigo pane before removing to orange. I changed the panes again at 6 o'clock P.M., putting them under indigo, and they passed the whole of July 3 under that pane, before removing to red on July 4. Their aversion to the violet rays, the only rays transmitted by the indigo pane that were not also transmitted by another pane, appeared to have then subsided, for they spent six whole days, from July 11 to July 16, inclusive, under the indigo pane. They appeared to have learned that it furnished a safe shelter for them.



N.

Experiment 2.—Using the artificial nest represented in the drawing, N, I put in, on June 9, five queens, thirty workers, and a teaspoonful of larvæ, all taken from a wild nest on the preceding day. The food-room was roofed with colorless glass, was used by the ants solely as a feeding place, and does not otherwise enter into the experiment. Over each of the three other rooms I placed a pane of colored glass—

Red, transmitting red rays only.

Yellow, transmitting red, orange, yellow, green, blue, indigo.

Blue, transmitting orange, yellow, green, blue, indigo, violet.

In 14 trials, occupying 14 days, the ants always removed from under the blue pane, whenever it was placed over them, and took shelter in another room. They removed 8 times to red, and 6 times to yellow.

In this experiment they always departed from the room to which violet rays were admitted, and settled in one of the two other rooms.

In order to secure an expression from the ants concerning particular colors I used Petri cells, offering a choice between only two panes. I made each test with newly captured ants, including one or more queens, ten or more workers, and some inert young.

Experiment 3.—Time, 40 days.

Red pane, transmitting red rays only.

Treble orange pane, transmitting red, green.

The ants showed no preference for either side of the cell. The panes were many times interchanged, but the interchange never caused their removal to the other side of the cell. The red and green rays were evidently as acceptable to them as were the red rays alone.

Experiment 4.—Time, 53 days.

Yellow pane, transmitting red, orange, yellow, green, blue, indigo.

Green pane, transmitting orange, yellow, green, blue, indigo.

The ants stayed indifferently through consecutive days under either pane, never removing from one side of the cell to the other on account of an interchange of the panes. They have therefore no preference for the red rays transmitted by the yellow pane.

Experiment 5.—Time, 50 days.

Red pane, transmitting red only.

Yellow pane, transmitting red, orange, yellow, green, blue, indigo.

The ants removed five times from under the yellow pane to the red; but were dilatory in their removals. They once waited three days, once four days, and once seven days, before removing.

Experiment 6.—Time, 20 days.

Yellow pane, transmitting red, orange, yellow, green, blue, indigo.

Blue pane, transmitting orange, yellow, green, blue, indigo, violet.

The ants always removed from under the blue pane within a few minutes after it was put over them. I interchanged the panes once or twice a day. In the first ten days they removed 20 times to the yellow side. The cause of the movement must have been either preference for the red or avoidance of the violet, and that the latter was the cause is indicated by Experiment 4.

Experiment 7.—Time, 21 days.

Indigo pane, transmitting yellow, green, blue, indigo, violet.

Violet pane, transmitting red, orange, yellow, green, blue, indigo, violet.

The ants removed five times from under the violet pane to the indigo side of the cell, but their movements were dilatory, and they stayed, toward the end of their sojourn, six consecutive days under the indigo pane, and then six consecutive days under the violet pane. This indicates lack of preference for the red and orange rays transmitted by the violet pane. The violet pane transmitted more of the violet rays than did the indigo pane.

Experiment 8.—Time, 21 days.

Blue pane, transmitting orange, yellow, green, blue, indigo, violet.

Colorless pane, transmitting red, orange, yellow, green, blue, indigo, violet.

The ants showed indifference concerning the two sides of the cell. They at first remained four days under the colorless pane, and when I then interchanged the panes, they remained ten consecutive days under the blue. I then reversed the panes again, and they remained under the colorless pane to the end of the test, seven days.

This indicates that the red rays transmitted by the colorless pane presented no definite attraction to them.

Experiment 9.—Time, 31 days.

Yellow pane doubled, transmitting red, orange, yellow, green, blue, indigo.

Green pane doubled, transmitting yellow, green, blue, indigo.

A daily interchange of the panes caused no removal of the ants. The red and orange transmitted on the yellow side did not attract them.

Experiment 10.—Time, 50 days.

Blue pane, transmitting orange, yellow, green, blue, indigo, violet.

Double indigo pane, transmitting yellow, green, blue, indigo, violet.

The ants stayed consecutive days on each side, and never removed on account of an interchange of the panes. They have not, therefore, a preference for the orange rays transmitted by the blue pane.

Experiment 11.—Time, 20 days.

Treble orange, transmitting red and green.

Double green, transmitting yellow, green, blue, indigo.

After three dilatory removals to the orange side, the ants became indifferent to their location in the cell.

Experiment 12.—Time, 30 days.

Treble orange, transmitting red, green.

Single orange, transmitting red, orange, yellow, green, blue.

The ants stayed indifferently under either pane, and never moved on account of interchanges of the panes. This indicates no preference for orange, yellow and blue rays.

Experiment 13.—Time, 45 days.

Double orange, transmitting red, orange, yellow, green.

Double green, transmitting yellow, green, blue, indigo.

The ants moved once to orange on account of interchange in the panes. The green side presented so little of blue and indigo under the spectroscope as to make the presence of those rays doubtful. The ants did not seek the red rays.

Experiment 14.—Time, 43 days.

Double orange, transmitting red, orange, yellow, green.

Single green, transmitting orange, yellow, green, blue, indigo.

The ants removed twice from green to double orange. This may indicate preference for red, or avoidance of the blue and indigo. The removals were dilatory, and the ants quickly became indifferent to the rays.

Experiment 15.—Time, 35 days.

Double orange, transmitting red, orange, yellow, green.

Yellow pane, transmitting red, orange, yellow, green, blue, indigo.

The action of the ants was the same as in the last experiment, and showed that the cause of the removals was not a preference for red, but an avoidance of the blue and indigo.

Experiment 16.—Time, 50 days.

Single orange, transmitting red, orange, yellow, green, blue.

Double green, transmitting yellow, green, blue, indigo.

The ants remained for consecutive days under each pane, and never removed on account of interchange of the panes. They have not, then, a preference for the red and orange transmitted by the orange pane.

Experiment 18.—Time, 43 days.

Single orange pane, transmitting red, orange, yellow, green, blue.

Single green pane, transmitting orange, yellow, green, blue, indigo.

The ants stayed consecutive days under each pane. I sometimes interchanged the panes twice a day, but such interchange never caused a change of location of the ant-group. The ants have not, then, a preference for red or for indigo.

Experiment 19.—Time, 22 days.

Single orange pane, transmitting red, orange, yellow, green, blue.

Single yellow pane, transmitting red, orange, yellow, green, blue, indigo.

The ants moved once to the orange side, and afterward stayed consecutive days under each pane. Interchanges of the panes never caused a removal of the ant-group. The ants have, then, but slight dislike for the indigo rays, the only rays in which the sides of the cell differed.

Experiment 20.—Time, 65 days.

Orange pane, transmitting red, orange, yellow, green, blue.

Violet pane, transmitting red, orange, yellow, green, blue, indigo, violet.

The ants removed hastily from under the violet as often as interchange of the panes was made, one or twice a day, for about twenty days. Thereafter they became indifferent to the violet rays. Their action indicates instinctive fear of the short wave-length rays, a fear that subsides with experience.

Experiment 21.—Time, 50 days.

Green pane, transmitting orange, yellow, green, blue, indigo.

Blue pane, transmitting orange, yellow, green, blue, indigo, violet.

The ants withdrew in haste from under the blue pane. I interchanged the glasses once or twice a day, and their removal from under the blue pane was speedily made, until about twenty days had elapsed, when they became dilatory in their removals and remained sometimes several days under the blue pane.

Experiment 22.—Time, 40 days.

Green pane, transmitting orange, yellow, green, blue, indigo.

Violet pane, transmitting red, orange, yellow, green, blue, indigo, violet.

The ants removed from under the violet pane and settled under the green pane as often as I interchanged the panes, once or twice a day, up to the twenty-fifth day, when they became dilatory and manifested increasing indifference to their roofing. The red rays did not neutralize the effect of the violet ones.

An analysis of the results of these experiments shows that the ants manifested no liking for any of the rays of light. If obliged to stay in light rays of some sort, the rays of longer wave-length are preferred to those of shorter wave-length. Dividing the spectrum, as we know it, into red, green and violet, we might say that to the ants' eyes red and green are most like the darkness that they prefer, and that violet is to them most luminous; or that the red and green are less visible to them than is the violet. In this regard the eyes of the ant appear to be the reverse of our own.

Our eyes perceive in the spectrum three fundamental colors—red, green and violet. The eyes of the ant may perceive there only two fundamental colors—one made up of the red and green rays, the other of the violet and ultra-violet rays.

After the experiments above recorded were completed, I put five queens and about three hundred workers, from a colony freshly brought from its natural nest, into each of five similar artificial nests, having opaque floors and walls and colorless glass roofs. The first nest I covered with cardboard, making its interior dark. The second I covered with panes transmitting only red and green rays, and in this the ants disposed themselves through the compartments in about the same way as did those in the first, the dark, nest. Over the third I put panes transmitting yellow, green, blue and indigo rays, and in this the ants disposed themselves with considerable regard to the shade afforded by the sides and partitions of the nest. Over the fourth I put panes transmitting only the rays at the violet end of the spectrum, and in this nest the ants disposed themselves with the same manifest effort to avoid the light as they did in the fifth nest, which was covered with colorless glass. Interchanging the panes caused the ants to rearrange themselves in accordance with the above scheme of relationship to the light.

Bearing in mind the fact that the ants showed no preference for red alone over the red and green (Experiment 3), it appears that the eye of the ant is not well adapted to the reception of light-rays whose wave-length is longer than in the violet rays; that it receives blue and indigo more perfectly than red, orange, yellow and green; and that there is a sudden increase of luminosity in the light-rays at that point in the spectrum where violet begins for our eyes.

The ants may discern colors, and yet have no preferences among the colors discerned. Color is determined by the wave-length in the light-ray, and since the ants discriminate between rays of different wave-lengths, they probably perceive color in the rays.

Sensitivity to the length of the wave indicates perception of color. They certainly discern white. Last year, when some of my Stenammas were intent upon the carrying of white pupæ through the maze into their nest, I dropped among the pupæ a few bits of white cord, cut to the size of the pupæ, and several ants picked up and carried bits of the cord a part of the way to the nest. They must have been deceived by the color, and must have lifted the bits of cord without smelling them, and on account of their color alone.

All my experiments emphasized the fact that the ants gradually lost their fear of the light, or of any modifications of it to which they were long exposed.

Ants hatched in the light, or hatched under violet or blue glass, and ants hatched in darkness and but a day or two old, all behaved under the colored panes exactly as did adult ants taken from the natural nests, showing that the withdrawal from light is instinctive, and that the instinct manifests itself from the beginning of the active life of the ant. I sequestered pupæ, and then segregated the ants hatched therefrom, and found that these ants, that had never associated with any other ants than those who had, like themselves, always lived in a Petri cell, behaved the same in regard to light-rays as did ants from the wild nests. The ant behavior in regard to light-rays is not the result of instruction from nor imitation of experienced elders.

I also repeated many of the experiments with ants five, ten and twenty days old, as well as with ants a few months old, reared in artificial nests, and found that this instinct prevailed at all ages, and over any sort of rearing. There was, however, a difference in the times within which ants of different ages become accustomed to the light-rays. The younger the ants the more quickly they ceased to move to the opposite side of the cell when I interchanged the panes.

The action of the ants when without inert young was essentially the same as when they had the care of eggs, larvæ and pupæ. The advantage gained in the experiments by the presence of the young was that the ants then reacted more speedily and definitely to the light-rays. The ants always grouped themselves upon or near the young, and there was so little of straggling that it seemed useless to count the few stragglers when reckoning results. The behavior of the ants toward the light-rays was the same whether queens were or were not present.

The withdrawal of the ants from the violet rays may have psychological relation to rain, or to some form of water. Four times when I put ants into cells of which one-half was covered with blue glass, the ants caught up their inert young and piled it all on top of the food enclosed in the cell, as if to raise the young out of the wet. This action on their part was so extraordinary as to cause me to make record of it. The ants living in my other Petri cells during the past two years have always assembled the young on the side of the cell opposite the food, and have in no case laid live larvæ or pupæ on the food-pile.

The plasticity of the ants is remarkably shown in their gradually learning to stay where they were never disturbed by me, under rays from which their instincts at first withdrew them.